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SOME QUANTITATIVE ANALYSIS ON THE CHRYSOMELID FAUNA OF THE RYUKYU ARCHIPELAGO *†

BY

Shinsaku KIMOTO

1. Preference

Recently the faunistic investigation of leaf beetles (or Chrysomelidae) of the Ryukyu Archipelago has been progressed remarkably. Those are mostly resulted by the project of " Zoogeography and Ecology of Pacific Area Insects" in connection with the Japan-U. S. Cooperative Science Program, "Scientific Expedition to the Yaeyama Group," organized by the Scientific Expediton Society of Kyushu University, " Scientific Expedition to the Tokara Islands " organized by the Osaka Museum of Natural History and so on.

Basing upon these materials, Kimoto and Gressitt (1966) compiled an inclusive revisional work on the Chrysomelid fauna of the Ryukyu Archipelago under the title of "The Chrysomelidae of the Ryukyu Archipelago." This paper is a result of my study on the Chrysomelid fauna of the Ryukyu Archipelago and Yakushima based on some quantitative methods.

I am indebted to the authorities of the Government of the Ryukyu Islands, University of the Ryukyus, Committee on Foreign Scientific Research of Kyushu University and Osaka Museum of Natural History, for their kind cooperation during the course of this study. My hearty thanks are due to Prof. K. Yasumatsu and Prof. Y. Hirashima, Kyushu University, Dr. S. Asahina, National Institute of Health, Prof. T. Takara, University of the Ryukyus and Dr. J. L. Gressitt, B. P. Bishop Museum, for providing me various facilities and encouragment. Also my sincere thanks are due to Prof. T. Ishihara, Ehime University, Mr. H. Hasegawa, National Institute of Agricultural Sciences and Mr. I. Hiura, Osaka Museum of Natural History, for giving me the opportunity to examine the materials preserved in their institutions.

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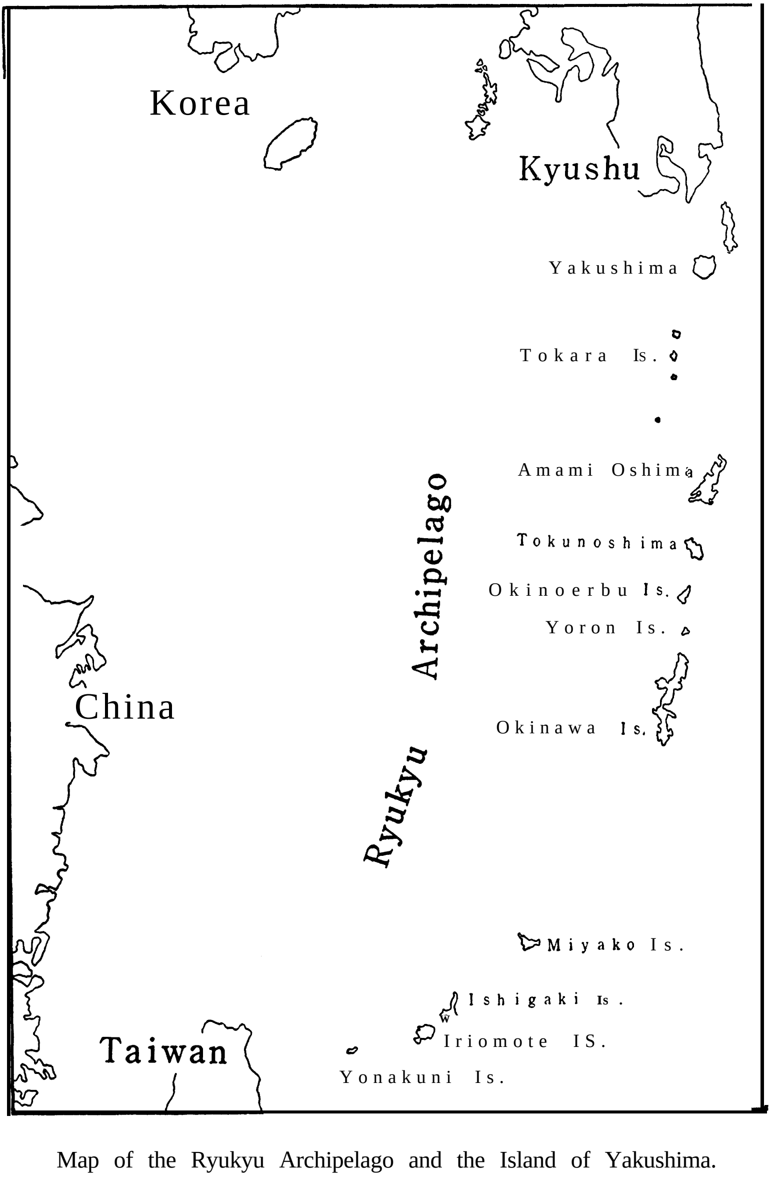

Map of the Ryukyu Archipelago and the Island of Yakushima.

Table 1. A list of the Chrysomelid species occurring in the Ryukyu Archipelago, including Yakushima.

	Yakushima	Tokara Is.	Amami-Oshima	Tokunoshima	Okinoerabu Is.	Yoron Is.	Okinawa Is.	Miyako Is.	Ishigaki Is.	Iriomote Is.	Yonakuni Is.
ZEUGOPHORINAE											
Auchenia (*Pedrillia*)											
gracilis unicolor							○				
flavonotata									○	○	
DONACIINAE											
Macroplea											
japana							0				
Donacia (*Cyphogaster*)											
provostii											0
CRIOCERTNAE											
Oulema											
atrosuturalis	0						○				
oryzae											0
Lema											
honorata	0								○	○	
paagai		○	○				○		○		○
coronata									○	○	○
adamsii	0										
diversa	0										
Lilioceris											
cyaneicollis		○	○				0				
subpolita	0										
CLYTRINAE											
Smaragdina											
ihai							0				
nipponensis			0				0		○	○	
quadratomaculata			0				0				
nigrifrons									0		

	Yakushima	Tokara Is.	Amami-Oshima	Tokunoshima	Okinoerabu Is.	Yoron Is.	Okinawa Is.	Miyako Is.	Ishigaki Is.	Iriomote Is.	Yonakuni Is.
CRYPTOCEPHALINAE											
Adiscus											
nigripennis									○	○	
Coenobius											
obscuripennis	○	○	○	○			0		○	○	○
nigrocastaneus									○	○	
Cryptocephalus											
loochooensis							○	○	○	○	
perelegans	○	○	○				○	○	○	○	○
CHLAMISINAE											
Chlamisius											
yakushimanus	○						0				
japonicus	○		0								
geniculatus	○		○	○			0				
LAMPROSOMATINAE											
Oomorphoides											
loochooensis	○		0				0				
okinawensis	○		○	○							
sakishimanus										0	
EUMOLPINAE											
Abirus											
fortuneii					○		○				
Acrothinium											
g. matsuii					0						
g. shirakii			0				0				
g. tokaraensis		0									
g. gaschkevitchii	○										
Colaspoides											
fulva	○		○	○			0		○	○	○
Platycorynus											
japonicus			0		○		○		○	○	○

	Yakushima	Tokara Is.	Amami-Oshima	Tokunoshima	Okinoerabu Is.	Yoron Is.	Okinawa Is.	Miyako Is.	Ishigaki Is.	Iriomote Is.	Yonakuni Is.
Pagria											
signata	○	○	○			0		○	○	○	○
Nodina											
chalcosoma	○	○	○							○	○
kraussi							0				
morimotoi							0				
Basilepta											
hirticolle	0										
uenoi		○	○				0				
fulvipes	0										
varicolor	0										
amamiense			○								
hirayamai	○	○	○	○			0		○	○	○
davidi		○	○				○	○	○		
Colasposoma											
auripenne		○	○		○		○	○	○	○	○
Rhyparida											
sakishimensis								○	○	○	○
Scelodonta											
sauteri		0									
lewisii	0										
Trichochrysea											
japana japana	0										
japana ***okinawana***			0				○		○		
Parascela											
cribrata										0	
Demotina											
major		○	○				0				
fasciculata	0										
decorata			0								
modesta	0		○	○	○		○		○	○	
Hyperaxis											

	Yakushima	Tokara Is.	Amami-Oshima	Tokunoshima	Okinoerabu Is.	Yoron Is.	Okinawa Is.	Miyako Is.	Ishigaki Is.	Iriomote Is.	Yonakuni Is.
fasciata	○										
Lypesthes											
fulvus	0	0	○		○		○		○		
itoi	○										
Aoria											
nucea	0										
Xanthonia											
placida		○									
CHRYSOMELINAE											
Chrysolina											
aurichalcea	0	○	○		○		0				
Phaedon											
brassicae	○	0	0				○				
Plagiodera											
versicolora			○								
Chrysomela											
vigintipunctata	○										
Linaeidea											
aenea insularis	0										
Phola											
octodecimguttata		○	○		○		0		○	○	
Gastrophysa											
atrocyanea			0								
Gonioctena (Sinomela)											
nagaii					○						
GALERUCINAE											
Isshikia											
isshikii			○				○				
Galerucella											
grisescens	0						○		○	○	

	Yakushima	Tokara Is.	Amami-Oshima	Tokunoshima	Okinoerabu Is.	Yoron Is.	Okinawa Is.	Miyako Is.	Ishigaki Is.	Iriomote Is.	Yonakuni Is.
Pyrrhalta											
yasumatsui			0				0				
humeralis							0				
nigricornis			0				0				
semifulva	0										
fuscipennis	0										
yoshimotoi							○				
Aulacophora											
bicolor			○		○		○	○	○	○	○
lewisii	0		0		0		○	○	○	○	
femoralis	○	○	○	○	○	○	○	○	○	○	○
loochooensis			0								
n. nigripennis	0										
n. nitidipennis			○	○			0		○	○	
Haplosomoides											
miyamotoi			0								
costata			0				0		○	○	○
Fleutiauxia											
armata	0										
Paridea											
angulicollis	0										
Morphosphaera											
coerulea			○		○		○	○	○	○	
japana		0									
Exosoma											
amamiensis			0				0		○	○	
chujoi	0										
Paraluperodes											
s. suturalis							○		○		
s. nigrobilineata					0						
Atrachya											
flavomaculata										0	

	Yakushima	Tokara Is.	Amami-Oshima	Tokunoshima	Okinoerabu Is.	Yoron Is.	Okinawa Is.	Miyako Is.	Ishigaki Is.	Iriomote Is.	Yonakuni Is.
menetriesi	○										
Monolepta											
pallidulum	0										
minor	○		○				0				
sakishimanum									○	○	
chujoi			0						○	○	
Haplosaenidea											
nciya *takei*										0	
Epaenidea											
elegans			0								
Dercetina											
azumai										0	
Epiluperodes											
ryukyuana									○	○	
Theopea											
aureoviridis							0		○	○	
Agelasa											
nigriceps	0										
Gallerucida											
oshimana			0								
ALTICINAE											
Norarthra											
cyaneum	○										
tibiale	0										
variabile			0				0				
Psylliodes											
subrugosa	○		○								
brettinghami			0								
difficilis		○	○								
angsticollis	○	○	○								
Chaetocnema											

	Yakushima	Tokara Is.	Amami-Oshima	Tokunoshima	Okinoerabu Is.	Yoron Is.	Okinawa Is.	Miyako Is.	Ishigaki Is.	Iriomote Is.	Yonakuni Is.
basalis	***0***	***0***	***0***	***0***			0		0	0	
discreta	○	○	○	○	○		***0***		***0***		
formosensis								***0***	***0***	***0***	***0***
concinnicollis		0	0		○						
ingenua	0										
Pseudoliprus											
kurosawai	0										
Lipromorpha											
difficilis			○	○				0			
Micrepitrix											
shirozui			0								
okinawana			○								
Neocrepidodera											
takara		0									
Clitea											
metallica							0		○	○	
Hespera											
lomasa		○	○				○	○	○		
Argopistes											
coccinelliformis			0				0				
S'haeroderma											
apicale	0										
quadrimaculatum	○	○	○				○	○	○	○	
fulvoapicale			0				0				
Schenklingia											
sau ***teri***			0				0				
Hemipyxis											
flavipennis	0										
shirakii							○			0	
foveolata			○				○				
balyi *cinctipennis*	○	○	○	○							
balyi okinawana							○				

	Yakushima	Tokara Is.	Amami-Oshima	Tokunoshima	Okinoerabu Is.	Yoron Is.	Okinawa Is.	Miyako Is.	Ishigaki Is.	Iriomote Is.	Yonakuni Is.
quadripustulata									○	○	○
plagioderoides										0	
takarai										0	
Longitarsus											
ihai							○	○	○	○	
bimaculatus	○		0				○	○	○	○	
boharti									0		
morrisonus		0									
haemorrhoidalis		○	○								
lewisii		○	○				○		○		
tokaranus		0							0		
amiculus	○	0									
Luperomorpha											
hidakai							0				
amamiana			○	○							
pryeri	○										
sakishimana									○	○	
Phyllotreta											
striolata	○	○	○		○		○	○	○	○	
Aphthona											
amamiana			○	○							
formosana	○	○	○	○	○		0		○	○	
perminuta	○										
nigrita	○	○	○				0				
strigosa	○										
Batophila											
acutangula	○										
latissima			0								
Horaia											
fulva			0				0		○	○	
Manobidia											
fulva			0								

	Yakushima	Tokara Is.	Amami-Oshima	Tokuonshima	Okinoerabu Is.	Yoron Is.	Okinawa Is.	Miyako Is.	Ishigaki Is.	Iriomote Is.	Yonakuni Is.
Manobia											
parvula		○	○				0		○	○	
lewisii	○		○	○			0				
gressitti								○	○	○	
Lipromela											
okinawana							0				
Ogloblinia											
flavicornis	○	○	○	○			0		○	○	
Zipangia											
lewisii			○				○				
nigricornis									○	○	
Zipanginia											
loochooana			0				0				
sakishimana									0		
Trachyaphthona											
sordida	0										
Altica											
cyanea	○	○	○	○		○	○	○	○	○	
caerulescens			○		○		○	○	○		
cirsicola							○		○		
HISPINAE											
Leptispa											
miyamotoi			0								
Dicladispa											
boutani										0	
Asamangulia											
yonakuni											0
CASSIDINAE											
Notosacantha											
sauteri ihai							0				
castanea ***loochooana***							0				

	Yakushima	Tokara Is.	Amami-Oshima	Tokunoshima	Okinoerabu Is.	Yoron Is.	Okinawa Is.	Miyako Is.	Ishigaki Is.	Iriomote Is.	Yonakuni Is.
Laccoptera											
quadrimaculata									○	○	
Thlaspida											
biramosa formosae					○		○				
Cassida											
(Taiwania) sauteri							○				
versicolor							○		○	○	
circumdata		○	○				○	○	○	○	○
(*Alledoya*) *vespertina*							○	○	○		
(Cassida) piperata	○		○				○		○	○	
Total number of species	71	41	84	19	20	3	87	22	66	62	20
Total number of genera	47	31	55	15	17	3	57	16	44	46	18

2. Material

The data treated in this paper is based upon the work compiled by Kimoto & Gressitt (1966) (Table 1). In addition to the species listed in Table 1, the following species have been recorded from several workers. However, such records are very doubious and not referred in Table 1. More detailed references of these records are available in the paper of Kimoto & Gressitt (1966). Those are:

Monolepta pallidulum Baly from Okinawa by Yuasa (1932).
Agelastica coerulea Baly from Okinawa by Chûjô (1935).
Sangariola punctatostriata Motschulsky from Okinawa by Chûjô (1935).
Altica viridicyanea (Baly) from Okinawa by Matsumura (1931).
Platypria echidna Guerin-Meneville from Okinawa by Gressitt (1939).
Aspidomorpha difformis (Motschulsky) from Okinawa by Yuasa (1932).

At present the faunistic investigation is better worked out on the principal islands in the archipelago. Those are Tokara Is. (mostly Nakanoshima and Takara-jima), Amami-Oshima, Okinawa, Ishigaki and Iriomote Is. from north to south. In addition to these, the fauna of Yakushima is treated for the comparison.

3. Indices used for the comparison of faunas

In this paper three following indices are used in order to express the degrees of the faunal similarities.

1) Nomura-Simpson's Coefficient (NSC)

$$NSC = \frac{c}{b}, \qquad a > b, \qquad 0 \geqq NSC \geqq 1$$

Where

a and *b* be number of species occurring in the 1st and 2nd areas.
c be number of common species between them.

This index was proposed by K. Nomura in 1939 and 1940 as Standard Common Ratio. Later, the same index was independently presented by G. G. Simpson in 1943 and name as Simpson's Coefficient by Hagmeier and Stultz in 1964. Since the name of Simpson's Coefficient has been used for several works on the N. American Mammal faunas and well known index, I wish to call this index as Nomura-Simpson's Coefficient (1939, 1940 & 1943), instead of Standard Common Ratio.

2) Harmonity Index of Subfamilies (HISF)

$$C_\lambda = \frac{2\sum_{i=1}^{\infty} n_{1i} \cdot n_{2i}}{(\lambda_1 + \lambda_2) N_1 \cdot N_2} \qquad 0 \leqq C_\lambda \leqq 1\,(\pm)$$

$$\lambda_1 = \frac{\sum_{i=1}^{\infty} n_{1i}(n_{1i} - 1)}{N_1(N_1 - 1)}, \qquad \lambda_2 = \frac{\sum_{i=1}^{\infty} n_{2i}(n_{2i} - 1)}{N_2(N_2 - 1)}$$

Where

N_1 and N_2 be total number of species occurring in the 1st and 2nd areas.
n_{1i} and n_{2i} be number of species of i-th subfamily of each area.

The value of C_λ will be about 1 when two areas belong to the same faunas and will be zero when no common subfamily is found between them. This index was first proposed by Morishita (1959) for the purpose of making the comparison of communities. As a preliminary attempt, Kimoto (1966) used this index for the comparison of rather large faunas such as Germany, Japan, Taiwan and so on. The result of this preliminary work well coincides with generally accepted theories on the zoogeography in insects and was proved that this method could be appropriate for the comparative study of such large faunas.

3) Harmonity Index of Genera (HIG)

$$C_\pi = \frac{2\sum_{i=1}^{\infty} n_{1i} \cdot n_{2i}}{(\sum \pi_1^2 + \sum \pi_2^2) N_1 \cdot N_2} \qquad 0 \leqq C_\pi \leqq 1$$

$$\sum\pi_1^2=\frac{\sum\limits_{i=1}^{\infty}(n_{1i})^2}{(N_1)^2}\ ,\qquad \sum\pi_2^2=\frac{\sum\limits_{i=1}^{\infty}(n_{2i})^2}{(N_2)^2}\qquad (\sum\pi=\frac{\sum\limits_{i=1}^{\infty}ni}{N}=1)$$

Where

N_1 and N_2 be total number of species occurring in the 1st and 2nd areas.
n_{1i} and n_{2i} be number of species of i-th genus of each area.

The figures of C_π value will be 1 when two areas belong to the same faunas and will be zero when no common genus is found between them. The C_π formula is different from C_λ formula, in using $\sum\pi^2$ as the Index of Diversity, instead of λ.

Table 2. Number of species and number of genus by islands. t: Number of species belonging to one genus. G: Total number of genus occurring in islands. N: Total number of species occurring in islands. $\left(G=\sum\limits_{t=1}^{\infty}g_t\ ,\ N=\sum\limits_{t=1}^{\infty}n_t\ ,\ n_t=t\cdot g_t\right)$.

t	1	2	3	4	5	Total	1	2	3	4	5	Total
Yakushima	31	10	4	2	0	47	31	20	12	8	0	71
Tokara Is.	21	2	2	0	1	31	26	4	6	0	5	41
Amami-Oshima	36	1.3	3	2	1	55	36	26	9 ,	8	5	84
Okinawa Is.	39	10	5	2	1	57	39	20	15	8	5	87
Ishigaki Is.	32	6	3	2	1	4 4	32	12	9	8	5	66
Iriomote Is.	35	8	1	2	1	46	35	16	3	8	0	62
---	g_1	g_2	g_3	g_4	g_5	G	n_1	n_2	n_3	n_4	n_5	i v

For the Harmonity Index of Genera, $\sum\pi^2$ is used as the Index of Diversity by the following reason. Relation between number of genera and number of species in the Ryukyu Archipelago and Yakushima are given in Table 2. From this table, it is apparent that frequency of genus which is consisted by one species is always the highest. The numerator of $\lambda, n_{1i}(n_{1i}-1)$, is zero when n_{1i} is zero or 1. Since the frequency of genus which is consisted by one species is always the highest, the figures of λ becomes lower. According to my calculation based on the figures presented in Table 8, the figures of C_λ values become almost 2.00 in some cases. The C_λ formula was proposed as an appropriate formula for any types of distributional patterns. However, this formula is not appropriate for the case that the distributional patterns follows the law of logarithmic series. We should remember the fact that C_λ formula was originally proposed for the purpose of studying the comparison of communities.

As stated by Morishita (1955), relationship between number of species and number of specimens follows the log normal law. By contrast to this, relationship between number of genera and number of species follows the law of logarithmic series, in accordance with the results presented by Williams (1954) and Morishita (1955).

Table 3. Figures of $N(1-p_t)$ calculated from Table 2. $\left(p_t=\frac{(n_1+n_2+\cdots+n_t)}{N}\right.$;

N: Total number of species occurring in islands, $\left. N=\sum_{t=1}^{\infty} n_t \right)$.

t	0	1	2	3	4	5
Yakushima	71	40	20	8	0	0
Tokara Is.	41	15	11	11	5	0
Amami-Oshima	84	48	22	13	5	0
Okinawa Is.	87	48	28	13	5	0
Ishigaki Is.	66	34	22	13	5	0
Iriomote Is.	62	27	11	8	0	0

To investigate the conformity with the law of logarithmic series on the relation between the number of genera and the number of species occurring in the Ryukyu Is. and Yakushima, Table 2 is presented. To avoid zero in the series of the figures, the following formula is used to transpose the given figures.

$$Y=\log N(1-p_t), \qquad p_t=\frac{(n_1+n_2+\cdots+n_t)}{N}$$

Where

N be the total number of species of each island.

n_t be the total number ot species belonging to genera which are consisted by t-species. $(n_t=t\cdot g_t)$

The figures of $N(1-p_t)$ are shown in Table 3. The fig. 1 is prepared by the figures shown in Table 3. As far as the data treated in the paper, the conformity with law of logarithmic series is remarkable.

Since the relation between number of genera and number of species in the Ryukyu Is. and Yakushima follows the law of logarithmic series, $\sum\pi^2$ is here used as Index of Diversity, instead of λ. For the purpose of the comparison of the faunal similarity, based on the relative representation of genera in an area, C_π formula is more appropriate one comparing with C_λ formula, because the figures of C_π formula strictly distribute zero to one.

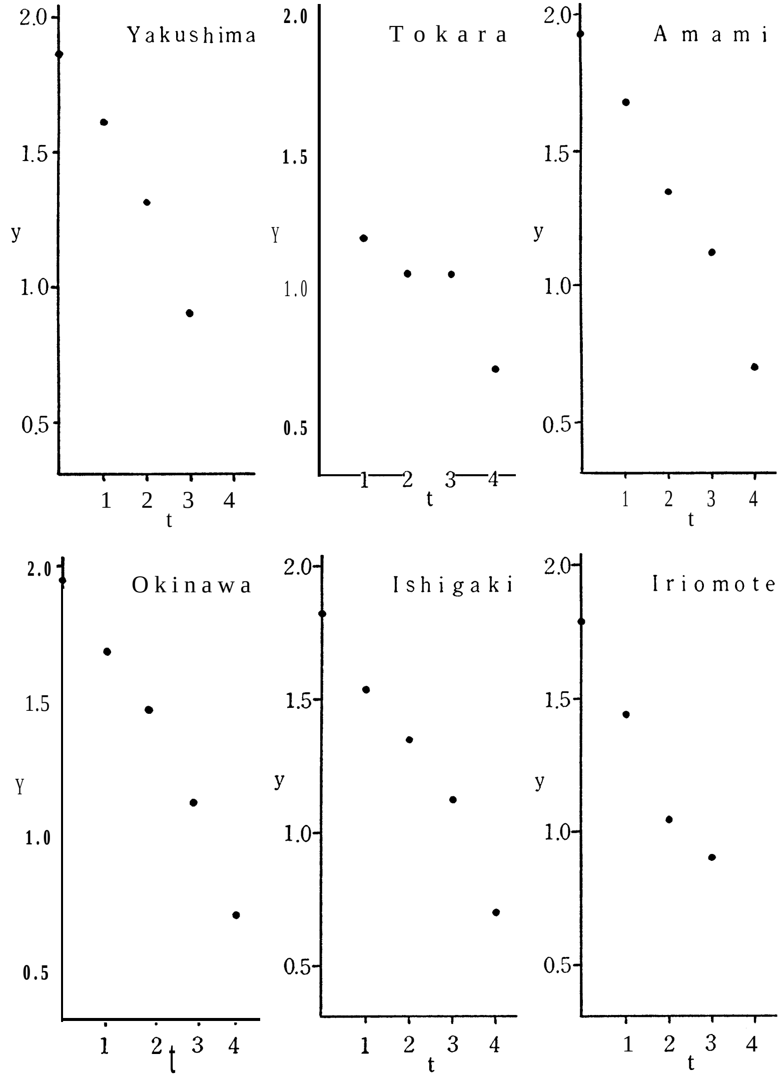

Fig. 1. Relation between number of species and number of genera in islands. $y=\log N(1-p_t)$, $p_t=\frac{(n_1+n_2+\cdots+n_t)}{N}$. t: number of species belonging to one genus.

4. Results

Based upon the indices presented in the previous paragraph, faunal similarity is calculated on the respective island.

1) Nomura-Simpson's Coefficient (NSC)

Table 4. Number of common species between islands.

Yakushima						
Tokara Is.	21					
Amami-Oshima	32	33				
Okinawa Is.	32	29	61			
Ishigaki Is.	22	22	38	45		
Iriomote Is.	20	17	32	36	49	
	Yaku	Tokara	Amami	Okinawa	Ishigaki	Iriomote

Table 5. Figures of Nomura-Simpson's Coefficient (NSC) between islands.

Yakushima						
Tokara Is.	0.512					
Amami-Oshima	0.450	0.804				
Okinawa Is,	0.450	0.707	0.726			
Ishigaki Is.	0,333	0.536	0.575	0.681		
Iriomote Is.	0.322	0.414	0.516	0.580	0.790	
	Yaku	Tokara	Amami	Okinawa,	Ishigaki	Iriomote

Number of common species between respective island is shown in Table 4. The figures of NSC-values are shown in Table 5. Fig. 2 is presented by a series of NSC-values on each island.

From Fig. 2, it is apparent that there is a strong gap between Yakushima and Tokara Is. and again weaker one between Okinawa and Ishigaki Is. Fig. 3 was presented in order to summarize the NSC-values treated in this paper. When NSC-values exceed 0.70, those islands are combined by a line with their NSC-value. Also, when the values exceed 0.80, those islands are combined by a wider line.

Among the islands, high figures of NSC-values are presented between Tokara Is. and Amami-Oshima (0.80), then between Ishigaki and Iriomote Is. (0.79) and between Amami-Oshima and Okinawa Is. (0.73).

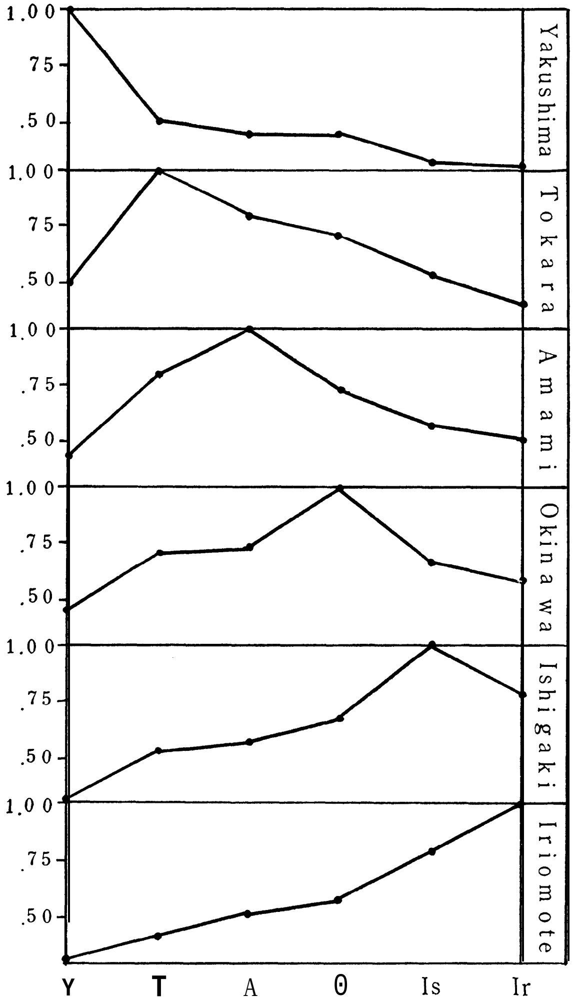

Fig. 2. Correlation graph based on figures of Nomura-Simpson's Coefficient (NSC).

As far as Nomura-Simpson's Coefficient concerns, the Ryukyu Archipelago including Yakushima can be classified into three island groups. The first group is consisted of a single island, Yakushima, the second group by Tokara, Amami-Oshima and Okinawa Is., and the third group by Ishigaki and Iriomote Is. The faunistic similarity between these islands groups is stronger between the second and the third groups than between the first and the second groups.

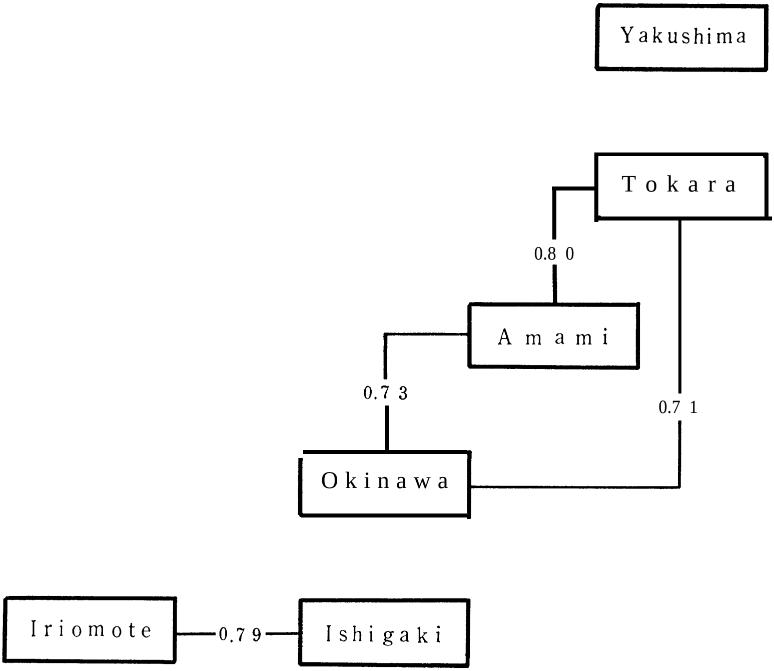

Fig. 3. NSC-figures exceeding 0.70 (wider line exceeding 0.80).

2) Harmonity Index of Subfamily (HISF)

The representation of number of species of each subfamily occurring in the islands is presented in Table 6. The figures of HISP values (C_λ) calculated from data presented in Table 6 are shown in Table 7. Fig. 4 is presented by a series of C_λ values on each island. From Fig. 4, it is evident that the curves for the Tokara Is. is different from the curves for the other islands. By contrast, the curves for the other islands are almost the same as each other. This results are very different from ones based on Nomura-Simpson's Coefficient. This interesting results will be discussed in the following chapter.

3) Harmonity Index of Genera (HIG)

The representation of number of species of each genus occurring in the islands is presented in Table 8. The figures of Hamonity Index of Genera (C_π)

Table 6. Geographical representation of species by subfamilies in islands.

	Zeugophorinae	Donaciinae	Criocerinae	Clytrinae	Cryptocephalinae	Chlamisinae	Lamprosomatinae	Eumolpinae	Chrysomelinae	Galerucinae	Alticinae	Hispinae	Cassidinae	Total
Yakushima	0	0	5	0	2	3	2	16	4	13	25	0	1	71
Tokara Is.	0	0	2	0	2	0	0	11	3	2	20	0	1	41
Amami-Oshima	0	0	2	2	2	2	2	15	5	16	35	1	2	84
Okinawa Is.	1	1	3	3	3	2	1	14	3	16	32	0	8	87
Ishigaki Is.	1	0	3	2	5	0	0	10	1	13	25	1	5	66
Iriomote Is.	1	0	2	1	5	0	1	9	1	15	22	1	4	62

Table 7. Figures of Harmonity Index of Subfamilies between islands (HISF; C_{λ} formula).

Yakushima	1.053					
Tokara Is.	.941	1.052				
Amami-Oshima	1.022	.982	1.037			
Okinawa Is.	1.013	.935	1.020	1.044		
Ishigaki Is.	1.011	.938	1.022	1.042	1.059	
Iriomote Is.	1.014	.895	1.018	1.034	1.052	1.063
	Yaku	Tokara	Amami	Okinawa	Ishigaki	Iriomote

calculated from the data presented in Table 8 are shown in Table 9. Fig. 5 is presented by a series of C_{π} values on each island. From Fig. 5, it is obvious that the curve for Tokara Is. is different from any of the other islands. At the same time there are some gaps between Yakushima and Amami-Oshima and between Okinawa and Ishigaki Is. respectively.

Fig. 6 is presented in order to summarize the HIG values (C_{π}) treated in this paper. When HIG values exceed 0.70, those islands are combined by a line with their HIG values. Also, when the values exceed 0.80, those islands are combined by wider line.

Among the islands treated in this paper, high figures of HIG values are seen between Amami-Oshima and Okinawa Is. (0.86) and between Ishigaki and Iriomote Is. (0.85).

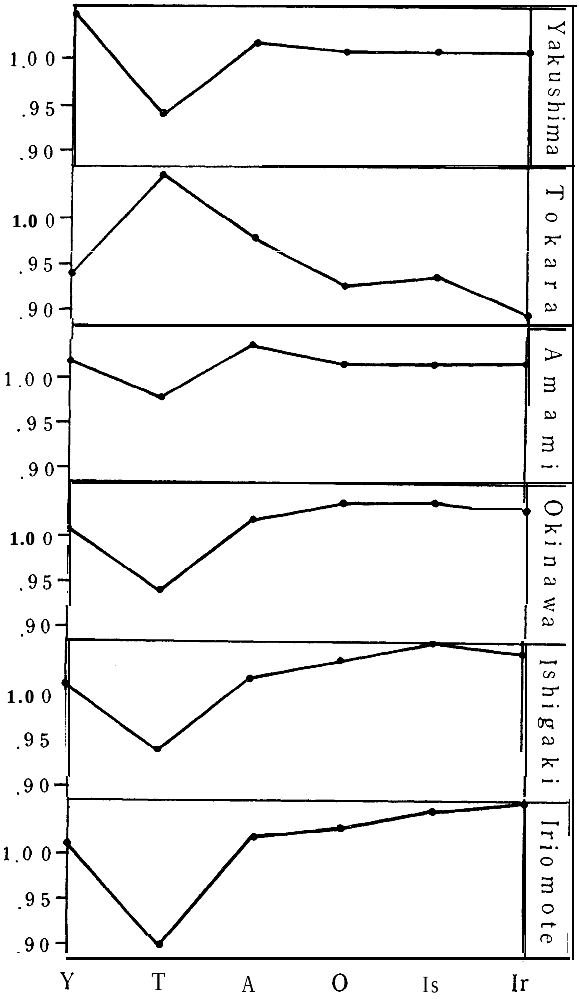

Fig. 4. Correlation graph based on figures of Harmonity Index of Subfamilies (HISF ; C_λ formula).

Table 8. Geogarphical representation of species by genera in islands

	Yakushima	Tokara Is.	Amami-Oshima	Okinawa Is.	Ishigaki Is.	Iriomote Is.		Yakushima	Tokara Is.	Amami-Oshima	Okinawa Is.	Ishigaki Is.	Iriomote Is.
Auchenia				1	1	1	**Linaeidea**	1					
Macroplea				1			**Phola**		1	1	1	1	1
Oulema	1			1			*Gastrophysa*			1			
Lema	3	1	1	1	3	2	**Isshikia**			1	1		
Lilioceris	1	1	1	1			**Galerucella**	1			1	1	1
Smaragdina			2	3	2	1	**Pyrrhalta**	2		2	4		
Adiscus					1	1	*Aulacophora*	3	1	5	4	4	4
Coenobius	1	1	1	1	2	2	*Haplosomoides*			2	1	1	1
Cryptocephalus	1	1	1	2	2	2	**Fleutiauxia**	1					
Chlamisius	3		2	2			*Paridea*	1					
Oomorphoides	2		2	1		1	*Morphosphaera*		1	1	1	1	1
Abirus				1			**Exosoma**	1		1	1	1	1
Acrothinium	1	1	1	1			*Paraluperodes*				1	1	
Colaspoides	1		1	1	1	1	**Atrachya**	1					1
Platycorynus			1	1	1	1	*Monolepta*	2		2	1	2	2
Pagria	1	1	1		1	1	**Haplosaenidea**						1
Nodina	1	1	1	2		1	*Epaenidea*			1			
Basilepta	4	3	4	3	2	1	**Dercetina**						1
Colasposoma		1	1	1	1	1	*Epiluperodes*					1	1
Rhyparida					1	1	*Theopea*				1	1	1
Scelodonta	1	1					**Agelasa**	1					
Trichochrysea	1		1	1	1		**Gallerucida**			1			
Parascela						1	**Nonarthra**	2		1	1		
Demotina	2	1	3	2	1	1	**Psylliodes**	2	2	4	2	1	2
Hyperaxis	1						**Chaetocnema**	3	3	2	2	3	2
Lypesthes	2	1	1	1	1		*Pseudoliprus*	1					
Aoria	1						*Lipromorpha*			1			
Xanthonia		1					*Micrepitrix*			2	1		1
Chrysolina	1	1	1	1			*Neocrepidodera*		1				
Phaedon	1	1	1	1			**Clitea**				1	1	1
Plagiodera			1				*Hespera*		1	1	1	1	
Chrysomela	1						*Argopistes*			1	1		

	Yakushima	Tokara Is.	Amami-Oshima	Okinawa Is.	Ishigaki Is.	Iriomote Is.
Sphaeroderma	2	1	2	2	1	1
Schenklingia			1	1		
Hemipyxis	2	1	2	3	1	4
Longitarsus	2	5	3	3	5	2
Luperomorpha	1		1	1	1	1
Phyllotreta	1	1	1	1	1	1
Aphthona	4	2	3	2	1	1
Batophila	1		1			
Horaia			1	1	1	1
Manobidia			1			
Manobia	1	1	2	2	2	2
Lipromela				1		
Ogloblinia	1	1	1	1	1	1
Zipangia			1	1	1	1
Zipanginia			1	1	1	
Trachyaphthona	1					
Altica	1	1	2	3	3	1
Leptispa			1			
Dicladispa						1
Notosacantha				2		
Laccoptera					1	1
Thlaspida				1		
Cassida	1	1	2	5	4	3
Total number of species	71	41	84	87	66	62
Total number of genera	47	31	55	57	44	46

Table 9. Figures of Harmonity Index of Genera between the islands (HIG; C_π formula).

Yakushima	1.000					
Tokara Is.	.660	1.000				
Amami-Oshima	.794	.672	1.000			
Okinawa Is.	.717	.608	.855	1.000		
Ishigaki Is.	.619	.711	.748	.783	1.000	
Iriomote Is.	.615	.574	.745	.764	.854	1.000
	Yaku	Tokara	Amami	Okinawa	Ishigaki	Iriomote

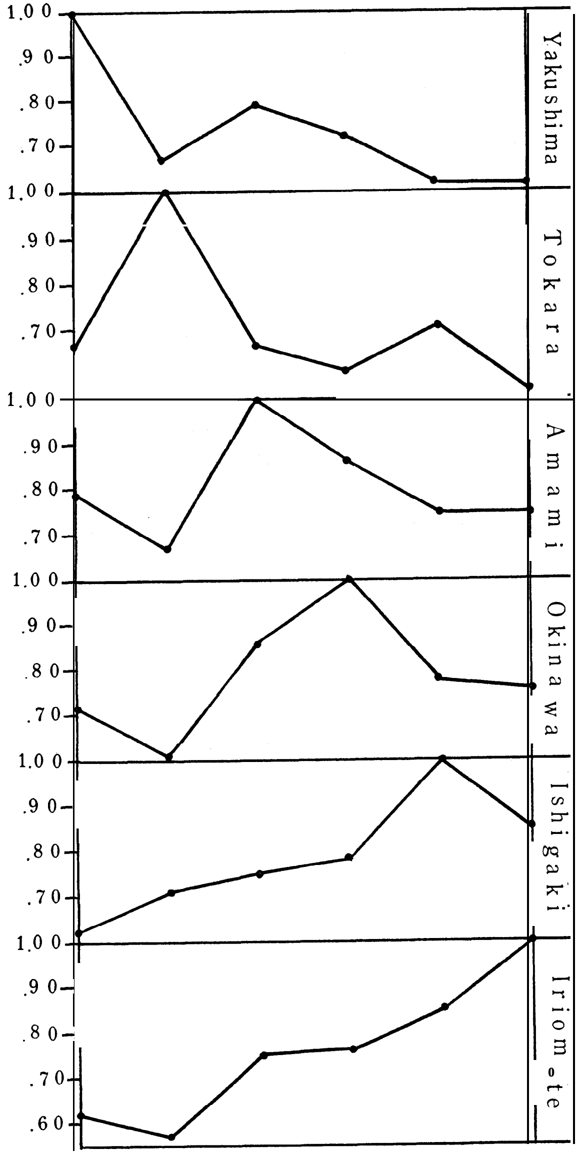

Fig. 5. Correlation graph based on figures of Harmonity Index of Genera (HIG; C_π formula).

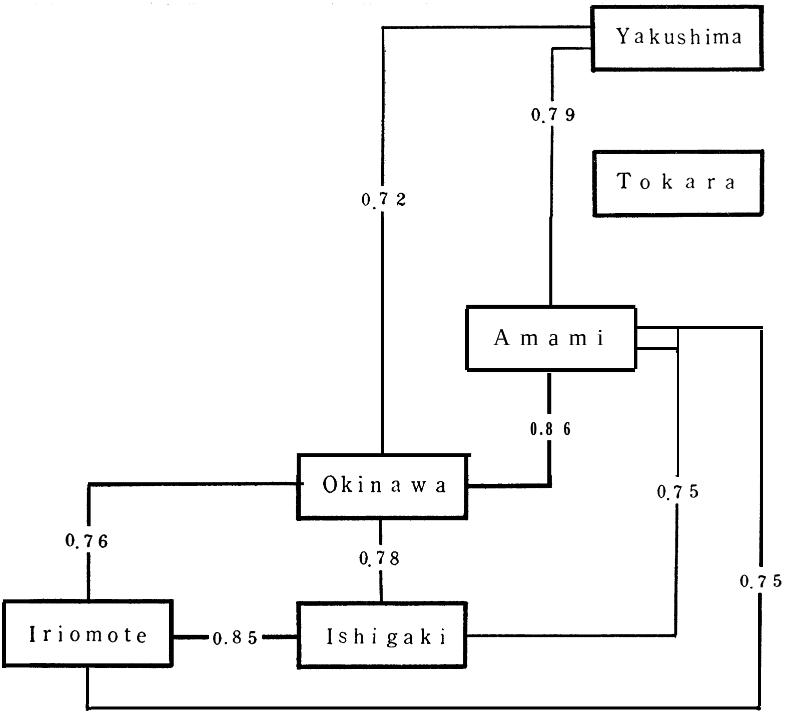

Fig. 6. HIG-figures exceeding 0.70 (wider line exceeding 0.80).

5. Discussion

The results obtained in the chapter 4 can be summarized as follow:

1) Among the Ryukyu Archipelago including Yakushima, the strongest discontinuity of the Chrysomelid fauna is marked between Yakushima and Amami-Oshima and next is between Okinawa and Ishigaki Is. The islands showing their high similarity are between Amami-Oshima and Okinawa Is. and between Ishigaki and Iriomote Is.

2) As far as the Chrysomelid fauna concerns, the fauna of the Ryukyu Archipelago including Yakushima is classified into three faunal groups. The first group is consisted by only an island, Yakushima, the second group by Amami-Oshima and Okinawa Is., and the third group by Ishigaki and Iriomote Is. Among these faunal groups, the faunal similarity is stronger between the second and the third faunal groups than the first and the second faunal groups.

3) From the index based on the number of common species (NSC), the Chrysomelid fauna of Tokara Is. indicates its close faunal similarity to Amami-Oshima and Okinawa Is. and not so to Yakushima. By contrast to this, the indices based on relative representation of subfamilies and genera (HISF and HIG) indicate that the fauna of Tokara is different from the other islands.

Tokara Is. is consisted by several small islands. Among them the larger ones are Nakanoshima, Takara- jima and Suwanose- jima. Among 41 species of the Chrysomelid beetles occurring in Tokara Is., only 3 species are not occurring on Nakanoshima but occurring in the other islands of the Tokara Is. Those are *Neocrepidodera* ***takara*** Nakane, ***Longitarsus tokaranus*** Nakane & Kimoto, and ***Cassida (Taiwania)*** *circumdata* Herbst. These three species are occurring on Takara-jima only in the Tokara Is. Thus the figures of Tokara Is. can be considered as an approximate value of Nakanoshima.

Meanwhile the geological history of Nakanoshima is different from the other islands of the Ryukyu Archipelago treated in this paper. According to the knowledges of geology, Nakanoshima was completely covered with sea water caused by sea-invasion in interglacial epoch in the Ryukyu and Kunigami Periods of Pleistocene, which are equivalent to the Gunz-Mindel and Mindel-Riis Interglacial Epochs respectively. According to the knowledges of the terrestrial snakes in the Ryukyu Archipelago (after Takara, 1962), none of the terrestrial snakes are occurring on Nakanoshima. It can be considered as a proof by the fact that Nakanoshima has been completely isolated from the other islands by ocean after these sea-invasions.

At present 37 species of the Chrysomelid beetles are occurring on Nakanoshima. This would mean that 32 species of the Chrysomelid beetles occurring on the island at present immigrated to the Nakanoshima from the other islands acrossing the ocean which is surrounding the island. Since the Chrysomelid beetles occurring on the island at present acrossed such barrier, immigrants to Nakanoshima were selected and composition of the present fauna became different from that of source area. Thus the fauna of Nakanoshima became a remarkable disharmonic fauna among the archipelago. One of the most important difference of the Chrysomelid fauna of Nakanoshima is relative dominance in Alticinae and inferiority in Galericinae.

The Nomura-Simpson’s Coefficient between the Tokara and Yakushima is relatively low ***(0.51)*** and between Tokara Is. and Amami-Oshima is the highest (0.80) and even between Tokara and Okinawa Is. is high enough (0.70). This would suggest that after the regression of ocean, the main portion of new immigrants to Tokara Is. would invased from Amami-Oshima and its southern islands.

Though the characteristic of Tokara Is. is very disharmonic among the archipelago, the fauna of Tokara Is. should be considered as a Subordinate Fauna of Amami-Oshima. The origin of the disharmonic character of the Chrysomelid fauna is considered as a result of sea-invasion of the Ryukyu and Kunigami Periods of Pleistocene.

Summary

1. The Chrysomelid fauna of the Ryukyu Archipelago and the island of Yakushima is analysed by some quantitative methods.

2. Indices used for the comparison of faunas are the following three indices.

i) Nomura-Simpson's Coefficient (= Nomura's Standard Common Ratio, 1939 & 1940, = Simpson's Coefficient, 1943).
ii) Harnomity Index of Subfamilies (C_λ formula).
iii) Harnomity Index of Genera (C_π formula).

3. Islands treated in this paper are classified into three faunal groups, according to their faunal similarities.

i) Yakushima. ii) Amami-Oshima and Okinawa Is. iii) Ishigaki and Iriomote Is.

4. The fauna of Tokara Is. is characteristic. According to the number of common species (Nomura-Simpson's Coefficient), Tokara Is. is related to Amami-Oshima and Okinawa Is. By contrast, the fauna of Tokara Is. is different from the other islands of the archipelago, in accordance with relative representation of subfamilies and genera, and represents a characteristic disharmonic fauna in having dominant Alticids and inferior Galerucids.

5. Though the fauna of Tokara Is. is disharmonic, this should be considered as Subordinate Fauna of Amami-Oshima, in having high persentage of common species with Amami-Oshima.

6. Origin of the disharmonic fauna of Tokara Is. is resulted by sea-invasions of the Ryukyu and Kunigami Periods of Pleistocene.

7. After the regression of ocean, the immigrants to Tokara Is. probably invased from Amami-Oshima and its southern islands, because of the high figures of the Nomura-Simpson's Coefficient with Amami-Oshima and its southern islands.

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